DEPARTMENT OF NATIONAL DEFENCE
CANADA

OPERATIONAL RESEARCH DIVISION

**DIRECTORATE OF OPERATIONAL RESEARCH (JOINT & LAND)**

**ORD PROJECT REPORT PR 0005**

# IRON TEMPLAR

## PARAMETRIC ANALYSIS OF ENGAGEMENT TIME AND HIT PROBABILITY OF AN ARMOURED FIGHTING VEHICLE

**by**

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**FEBRUARY 2000**

OTTAWA, CANADA

National Defence Défense nationale

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OTTAWA, ONTARIO FEBRUARY 2000

## ABSTRACT

Over the past few years, DLR has been investigating currenttechnologies to improve the speed of application and the accuracy of direct fire from fire support vehicles. This study examines the effects of reducing the time required to engage a target and of increasing the probability of hit of an armoured fighting vehicle in a defensive and offensive posture. The results show that the effectiveness of the vehicle consistently and significantly improved as the time to engage a target decreased and as the probability of hit increased. The results also showed that decreasing the time to engage a target had a greater impact than increasing the probability of hitting it. Considering the fact that probability of hit is also range dependent, the study recommends that technologies that decrease the time required to engage a target be given a higher priority to those that increase the probability of hit.



## RÉSUMÉ

Depuis quelques années, DBRT a étudié les technologies actuelles afin d'améliorer la vitesse d'application et la justesse du tir direct à partir des véhicules de tirs d'appui. Cette étude examine les effets de la réduction du temps requis d'engagement et de l'augmentation de la probabilité de frappe d'un véhicule blindé dans une vignette défensive et offensive. Les résultats indiquent que l'efficacité du véhicule s'améliorait, de façon conséquente et significative, au fur et à mesure que le temps pour engager la cible diminuait et que la probabilité de tuer augmentait. Les résultats ont aussi montré que la réduction du temps nécessaire pour engager une cible avait un plus grand impact que l'augmentation de la probabilité de frapper cette cible. Sachant que la probabilité de frappe dépend aussi de la distance, l'étude recommande que les technologies qui diminuent le temps nécessaire pour engager une cible obtiennent une priorité supérieure à celle accordée aux technologies qui augmentent la probabilité de frappe.

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# IRON TEMPLAR

# PARAMETRIC ANALYSIS OF ENGAGEMENT TIME AND HIT PROBABILITY OF AN ARMOURED FIGHTING VEHICLE

## I. INTRODUCTION

### BACKGROUND

1. Over the past few years, the Director Land Requirements (DLR) has been investigating current technologies to improve the speed of application and the accuracy of direct fire from fire support vehicles. Under the scientific authority of the Chief of Research and Development (CRAD), a project was approved for industry to build a testbed vehicle capable of assessing: increases in detection and acquisition ranges; crew workload during engagements; reduction in engagement times; improvements to system accuracy; and increases to hit probabilities from both a stationary and a moving posture.

2. This R&D project, D6374 - Advanced Land Fire Control System (ALFCS), is currently under contract to Computing Devices Canada (CDC) and reached the milestone ALFCS Build 3 in March 1999. The Army Research Board (ARB) tasked DOR(J&L) to provide a parametric analysis of the improvements to the fire control system (FCS) of the Army's direct fire vehicles (DFV) to determine what effects such improvements could have on the battlefield and to evaluate outcomes from CDC's testbed. The sponsor for the project was DLR 3. The project was entitled "IRON TEMPLAR".

### AIM

3. The aim of this study was to assess the potential impact of increasing the probability of hit and decreasing the engagement time of the current FCS of the Army's DFV(s).

**SCOPE**

4. The scope of the study was as follows:

   a. War gaming was used as a venue for gathering the necessary data;

   b. The study used attack and defence scenarios from a previous war game. Troop/platoon – squadron/company size friendly and opposing forces were used;

   c. Battlefield synergy was reduced to its simplest level with BLUE and RED forces having main battle tanks (MBT) of near-equal technological capability. All supporting anti-tank fires, indirect fires and other normal combat support was removed from the engagement scenarios in order to focus on the interactions between the main battle tanks;

   d. The LEOPARD C2 tank was used as the BLUE DFV for the study; and

   e. Armour-Piercing Fin Stabilized Discarding Sabot (APFSDS) ammunition was used by BLUE.

**OBJECTIVES**

5. The objectives of IRON TEMPLAR were to assess:

   a. The results of reducing the time to engage a target. This time was considered a composite of: the time to lay the main armament in the direction of the target (lay time); the time required to confirm the target in terms of detection and identification and initiate firing (aim time); and the time required to reload after firing and be ready to repeat or accept another engagement (reload time); and

   b. The results of improving the probability of achieving a first round hit from both a defensive and attack posture (probability of hit).

# II. METHODOLOGY

## TOOLS

6. The Janus war-game was the only tool used in this study.

### Janus

7. Janus is a computer war game that simulates combat systems and the environment at the tactical level. Military players control the movement of forces and react to detections and engagements by interacting with a computer screen. The screens provide each user with a two-dimensional overhead view of the battlefield, icons that represent the forces involved, and a menu that allows the user to control the icons. Forces are defined as a group of systems. The probability of each system detecting, killing, and surviving must be accurately defined in the Janus database. Janus is a versatile tool for simulating ground combat and is capable of modelling many of the factors that influence the outcome. Examples are: day and night visibility, weather and its effects, rotary and fixed-wing aircraft, minefield employment and breaching, resupply, engineer support, and nuclear, biological and chemical (NBC) warfare.

8. Results from Janus, like any war game, are affected by the assumptions and modelling techniques used by the model's developers. For example, the user interacts with a graphical screen that provides perfect situational awareness of players' forces; therefore, it is assumed that all forces have battle management systems, and commanders have near-perfect command and control. Human factors such as training, morale, fatigue, fear, and aiming error are not considered. Consequently, weapon systems perform at their theoretical maximum rather than at their operational norm. These and other modelling limitations do not diminish the credibility of Janus output but bear consideration when evaluating results. Janus is a powerful tool for comparing two or more systems or various tactics as the limitations of the model apply equally to all games.

9. The study was conducted as an interactive, two-sided, closed war game using Janus version 6.0 (C4) and DOR(J&L)'s unclassified database version 6.01. Janus was then used in its "Autojan" mode to replay each scenario using different random numbers to generate data using a Monte Carlo technique. This technique provides reasonable results if

the scenario is small in scope in both space and time. The scenario was gamed using 50 metre resolution digitized terrain of the HUNFELD and BAD HERSFELD areas of Germany.

## PARAMETRIC VARIATION

10. The baseline values used in this study were derived from data contained in the Janus database and were validated by an experienced Armour Branch officer. To help identify the results associated with each variation, the different values were each given a designator. The designators T1 to T4 were used for the engagement time variations which were based on military judgement to yield a uniform decrease in engagement time. The designators PH1 to PH5 were used for the probability of hit variations which were also chosen to yield a uniform increase in probability of hit.

### Time-To-Engage Parameter

11. The variation of the time-to-engage parameter is shown in Table 1.

Table 1

Variation in Time-to-Engage a Target

| Time to Engage (Seconds) | Designator | | | | |
|---|---|---|---|---|---|
| | Baseline | T1 | T2 | T3 | T4 |
| Lay Time | 4 | 4 | 3 | 2 | 1 |
| Aim/Reload Time | 6 | 4 | 3 | 2 | 1 |
| Total Time | 10 | 8 | 6 | 4 | 2 |

### Probability of Hit Parameter

12. Probability of hit (PH) for a gun is dependent on many parameters such as engagement range and the size of the target. In this study, probability of hit varied with engagement range and whether the target was exposed or in defilade. A defilade target is one that has only the turret exposed. The variation in the probability of hit parameter is shown in Table 2 at the stated range and target exposure.

Table 2

Variation in Probability of Hit

| POSTURE | DESIGNATOR | Engagement Range (metres) | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 100 | 500 | 1000 | 2400 |
| DEFILADE | Baseline | 1.00 | 1.00 | 0.92 | 0.60 | 0.20 |
| | PH 1 | 1.00 | 1.00 | 0.93 | 0.65 | 0.30 |
| | PH 2 | 1.00 | 1.00 | 0.94 | 0.70 | 0.40 |
| | PH 3 | 1.00 | 1.00 | 0.95 | 0.75 | 0.50 |
| | PH 4 | 1.00 | 1.00 | 0.96 | 0.80 | 0.60 |
| | PH 5 | 1.00 | 1.00 | 0.97 | 0.85 | 0.70 |
| EXPOSED | Baseline | 1.00 | 1.00 | 1.00 | 0.95 | 0.50 |
| | PH 1 | 1.00 | 1.00 | 1.00 | 0.96 | 0.60 |
| | PH 2 | 1.00 | 1.00 | 1.00 | 0.97 | 0.70 |
| | PH 3 | 1.00 | 1.00 | 1.00 | 0.98 | 0.80 |
| | PH 4 | 1.00 | 1.00 | 1.00 | 0.99 | 0.90 |
| | PH 5 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

13. The final engagement range of 2400 metres represents the maximum effective range of the gun. Probability of hit values for intermediate engagement ranges were linearly interpolated. Examples of PH curves from Table 2 are shown graphically in Figure 1.

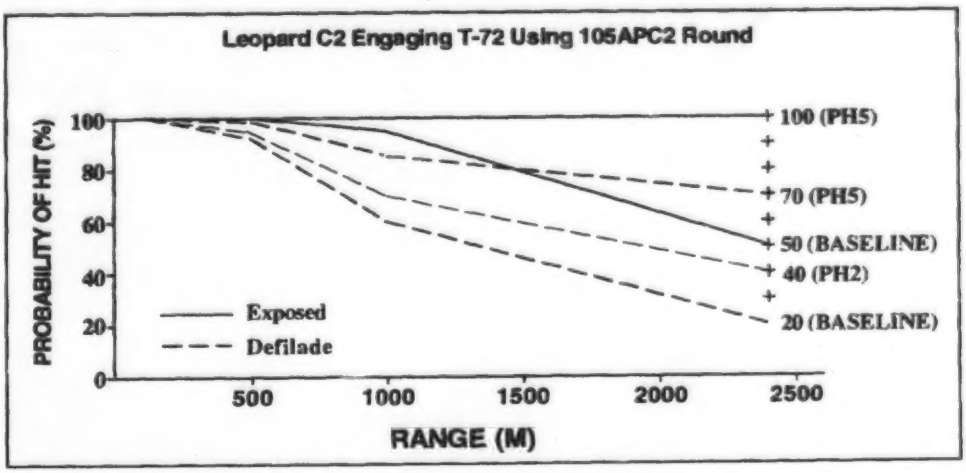


Figure 1: Probability of Hit Variation

**MEASURES OF EFFECTIVENESS**

14. The following Measures Of Effectiveness (MOE) were used in the parametric analysis:

a. Lethality. How many RED tanks were destroyed?

b. Survivability. How many losses did the BLUE force incur?

**SCENARIOS**

15. The war game was played using simplified offensive and defensive vignette situations on mixed terrain. The vignettes were developed from a larger battle group scenario based on a recently completed DOR(J&L) war game.

# III. RESULTS

## GENERAL

16. The following results are based on the average of twenty Autojan runs for each vignette.

## DEFENSIVE VIGNETTE

17. Force Size. The BLUE force was based on a tank troop of four LEOPARD C2 tanks. The force defended against a RED force tank company equipped with thirteen T-72 tanks.

18. Opening Scenario. A tank-equipped armoured regiment successfully defeated the Forward Security Element of a RED force Motor Rifle Regiment (MRR) attack. It was then tasked to immediately re-group and re-deploy elements to the EAST to block enemy flanking units from penetrating into the eastern flank. Part of this task went to a tank troop that was ordered to take up a hasty blocking position facing SOUTH and WEST from the saddle feature on hill features 371 and 386 SOUTHEAST of the town of OBERMEISENBORN.

19. Game History. As the BLUE force tanks moved into hastily-prepared, hull-down positions, what appeared to be an enemy tank company crested a knoll 2500 m to the SOUTHWEST. The T-72s were in extended line with another tank platoon immediately to the rear. The BLUE troop opened fire. The RED tank company commander left one T-72 tank platoon on a fire line on a knoll to the EAST of the first contact. The remainder of the T-72 tanks continued straight at the centre of mass of the defending BLUE force. The BLUE force continued to block from this position until one side or the other was totally destroyed or the forces broke contact with each other due to the loss of line of sight. The vignette is shown on the next page in Figure 2.

Figure 2: The Defensive Vignette

**Parametric Results**

20. The results of the time-to-engage parameter are shown in Figure 3. Autojan runs for the T3 case were not performed as they were not considered necessary to define the trend.

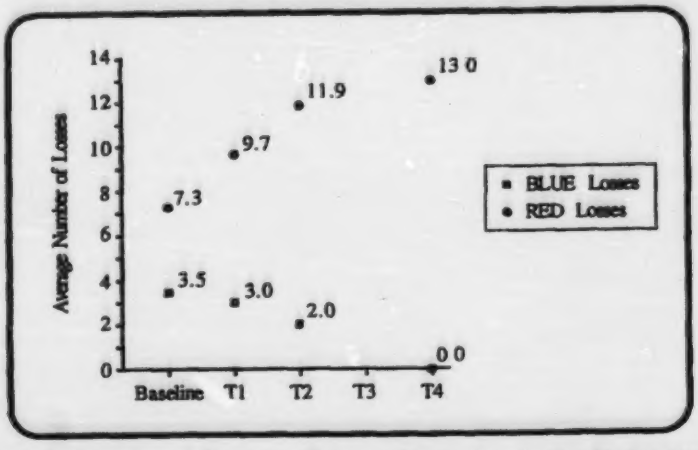


Figure 3: Results of Time-to-Engage Variation in the Defensive Vignette

21. The results of the probability of hit parameter are shown in Figure 4. Autojan runs for the PH1 and PH4 cases were not performed as they were not considered necessary to define the trend. The average kill range for BLUE in these vignettes was 2.0 km.

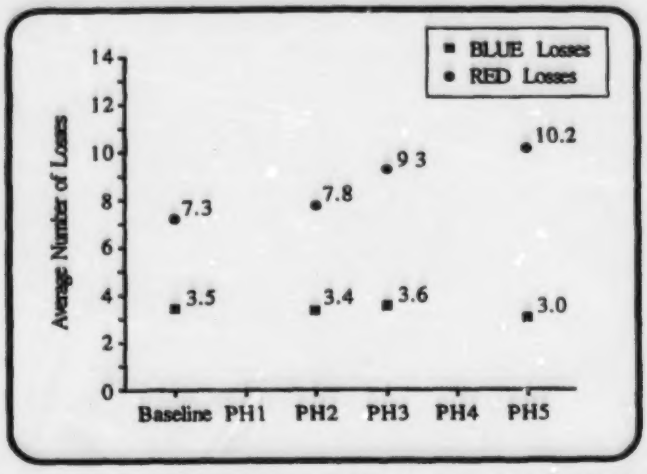


Figure 4: Results of Probability of Hit Variation in the Defensive Vignette

22. Preliminary analysis of results examining the synergy of combining an increase in hit probability with a decrease in engagement time did not show any significant improvement over those obtained from the engagement time analysis. Further analysis was not pursued because of time restraints and higher priority projects.

**Statistical Results**

23. In Figure 3 it is clear that both the BLUE losses and the RED losses are strongly correlated with the time-to-engage parameter. BLUE losses steadily decrease as time-to-engage decreases while RED losses steadily increase as time-to-engage decreases. Application of a robust statistical test (Pitman's test for trend in bivariate data) confirms that both of these observed trends are well beyond chance variation at the 99% confidence level.

24. In Figure 4 the trends are not as clear. The RED losses steadily increase as probability of hit increases whereas the BLUE losses seem to be relatively constant despite the increasing probability of hit. The same statistical test noted above was applied to the Autojan parametric results for RED and BLUE losses versus probability of hit. Results indicated that the increasing trend of RED losses with increasing probability of

hit is statistically significant at the 99% confidence level. However, the test indicated that the BLUE losses do not show a statistically significant trend with increasing probability of hit. One can therefore conclude that within the parameter values used in the study, increasing probability of hit had no significant effect on BLUE losses.

**Summary**

25. In the time-to-engage analysis, there was a statistically significant increase in the number of RED losses and a significant decrease in the number of BLUE losses. From a starting strength of four (4) tanks, the average number of BLUE losses decreased from 3.5 for the baseline to no losses for the T4 case, representing a 100% decrease in losses. At the same time, the average number of RED losses increased from 7.3 to 13.0 of the initial thirteen (13) tanks, representing an increase of 78%. Therefore, as the time required to engage a target decreased, there was a consistent and significant increase in the number of RED losses and decrease in the number of BLUE losses.

26. In the probability of hit analysis, there was a statistically significant increase in the number of RED losses, but there was no significant change in the number of BLUE losses. The average number of RED losses increased from 7.3 for the baseline to 10.2 for the PH5 case, representing an increase of 40%. Therefore, as the probability of hitting a target increased, there was a consistent and significant increase in the number of RED losses, but there was no significant effect on the number of BLUE losses. The average engagement range of the BLUE tanks must also be considered when evaluating this result. The vignette chosen allowed BLUE to engage RED at the maximum effective range of the 105mm gun. If the vignette changed so that BLUE could not engage at long range or BLUE engaged at the more typical range of 1800 metres, the results would be much different. Little or no effect on increasing PH would be seen in such a vignette because the 105mm gun is already very accurate at closer ranges and very little improvement is possible.

**OFFENSIVE VIGNETTE**

27. The BLUE force was based on a tank squadron (-) equipped with ten LEOPARD C2 tanks. The force attacked the remnants of a RED force tank platoon equipped with three T-72 tanks.

28. Opening Scenario. The BLUE Battle Group had halted the advance of the RED MRR. Survivors from the MRR and second echelon forces attempted to flank the battle group. The Commander of the CMBG ordered the tank squadron (depleted to 50% strength) supporting the BLUE Battle Group to immediately move to the flank of the adjacent Battle Group and seize the high ground. From this position, the Commander intended that the squadron(-)support the brigade's counter-attack force. The brigade's counter-attack force was to attack and destroy the enemy threatening to outflank the Battle Group. The squadron (-) advanced, leapfrogging by troops.

29. Game History. As the scenario opened, the EAST tank troop was in an overwatch position. The tank troop on the WEST was moving cross-country in open ground, followed immediately by the Squadron OC and the dozer tank. At this point, the mobile force came under tank fire from the area of a dominating rise approximately two kilometers away to the NORTHEAST. On order from the OC, the six tanks stopped, returned fire and jockeyed. At the same time, the troop in overwatch on the right was ordered to move forward quickly along the spur in the dead ground and form a hasty fire base to support a quick attack. Once this troop was in a position to provide accurate fire on the objective, the left troop and the two squadron headquarters tanks attacked the enemy tank positions using maximum fire and best cross-country speed. Because of the elevation of the enemy position and the similar elevation of the BLUE fire base, the four tanks from the fire base were able to continue firing at the objective. The attack continued until one side or the other was totally destroyed or the forces broke contact with each other due to the loss of line of sight. The vignette is shown below in Figure 5.

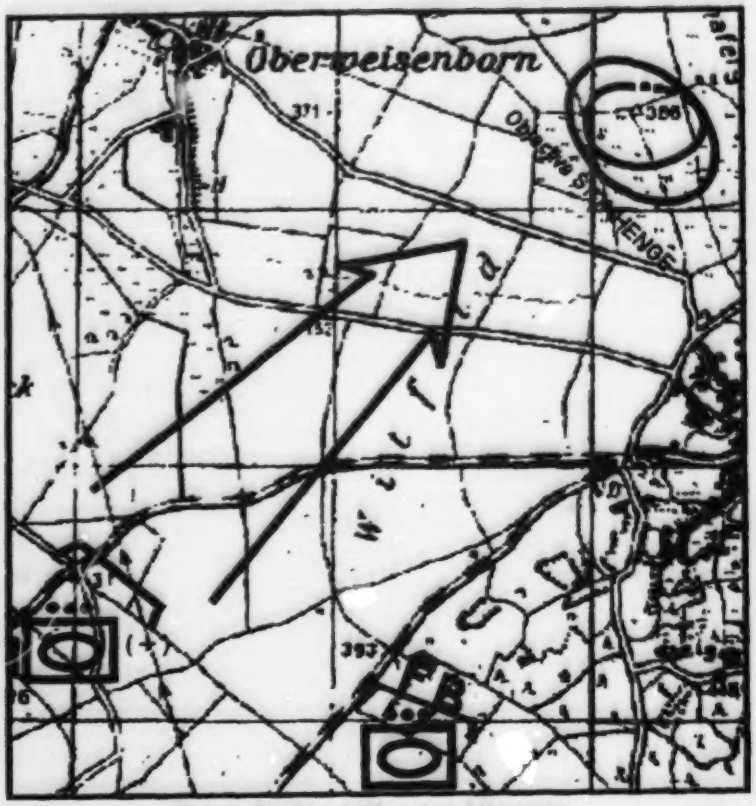


Figure 5: The Offensive Vignette

30. The results of the time to engage parameter are shown in Figure 6. Autojan runs for the T3 case were not performed as they were not considered necessary to define the trend.

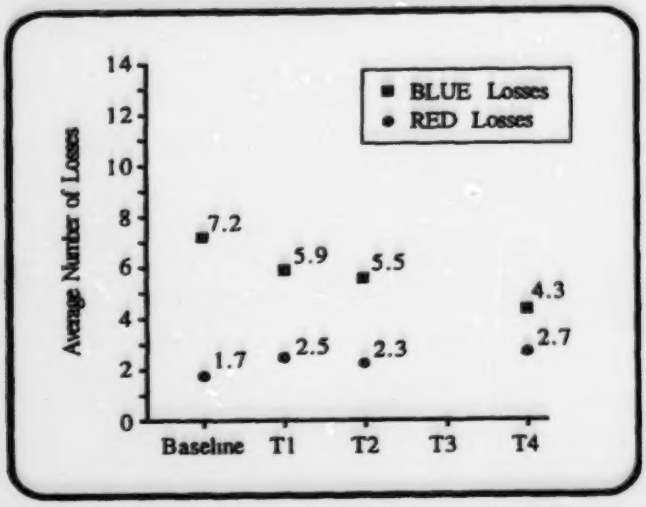


Figure 6: Results of Time-to-Engage Variation in the Offensive Vignette

31. The results of the probability of hit parameter are shown in Figure 7. The average kill range for BLUE in these vignettes was 2.28 km. Again Autojan runs for the PH4 case were not performed as they were not considered necessary to define the trend.

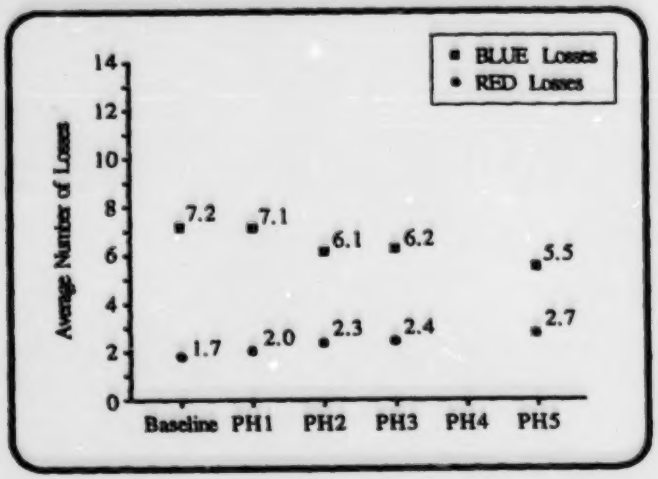


Figure 7: Results of Probability of Hit Variation in the Offensive Vignette

**Statistical Results**

32. The results of the statistical analysis using Pitman's test were that, in all cases, there was sufficient evidence to reject the hypothesis that the variables are independent, and therefore, one can conclude that the variables are correlated.

**Summary**

33. In the time-to-engage analysis of the Offensive Vignette, there was a statistically significant increase in the number of RED losses and a significant decrease in the number of BLUE losses. From a starting strength of ten (10) tanks, the average number of BLUE losses decreased from 7.2 for the baseline to 4.3 for the T4 case, representing a 40% decrease in losses. At the same time, the average number of RED losses increased from 1.7 to 2.7 of the initial three (3) tanks, representing an increase of 59%. Therefore, as the time required to engage a target decreased, there was a consistent and significant increase in the number of RED losses and decrease in the number of BLUE losses.

34. In the probability of hit analysis of the Offensive Vignette, there was a statistically significant increase in the number of RED losses and a significant decrease in the number of BLUE losses. The average number of BLUE losses decreased from 7.2 for the baseline

to 5.5 for the T4 case, representing a 24% decrease in losses. At the same time, the average number of RED losses increased from 1.7 to 2.7, representing an increase of 59%. Therefore, as the probability of hitting a target increased, there was a consistent and significant increase in the number of RED losses and decrease in the number of BLUE losses. Once again, a reduced effect of increasing hit probability would be seen if BLUE could not engage at the maximum effective range of the Leopard's 105mm gun.

## IV. CONCLUSIONS AND RECOMMENDATIONS

35. As one would expect, the results clearly show that, in general, the effectiveness of the BLUE force consistently and significantly improved as their time to engage a target decreased or their probability of hit increased. The results also showed that decreasing the time to engage a target had a greater impact than increasing the probability of hitting it. Considering the effect of engagement range on hit probability, this impact would have been even more pronounced if the situation changed and the BLUE force could not engage RED at the maximum effective range of the Leopard's 105mm gun. The improved effectiveness of increasing hit probability could be negligible if the average engagement range was reduced. It is therefore recommended that technologies that decrease the time required to engage a target be given a much higher priority than those that increase the probability of hit.

# V. REFERENCES

1. Secretarial Note to 1150-110 (DLR Prog 3) 7 Apr 98 – Mins of ARB.

2. DLR/DOR(J&L)/RWGT project correspondence through Apr 98

UNCLASSIFIED

Security Classification of Form
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DOCUMENT CONTROL DATA
(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1 ORIGINATOR (the name and address of the organization preparing the document Organizations for whom the document was prepared e.g. Establishment Sponsoring a contractor's report, or tasking agency, are entered in Section 8).

Operational Research Division
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2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable)

UNCLASSIFIED

3 TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title)

IRON TEMPLAR Parametric Analysis of Engagement Time and Hit Probability of an Armoured Fighting Vehicle

4. AUTHORS (last name, first name, middle initial)

Ormrod, Mike K.; Hewitt, Peter W. Maj; and Stewart, James C. Maj

| 5. DATE OF PUBLICATION (month Year of Publication of document) | 6a. NO OF PAGES (total containing information. Include Annexes, Appendices, etc.) | 6b. NO OF REFS (total cited in document) |
|---|---|---|
| FEBRUARY 2000 | 21 | 2 |

7 DESCRIPTIVE NOTES (the category of document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Project Report

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development Include the address).

DLR

| 9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.) | 9b. CONTRACT NO (if appropriate, the applicable number under which the document was written.) |
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Over the past few years, DLR has been investigating current technologies to improve the speed of application and the accuracy of direct fire from fire support vehicles. This study examines the effects of reducing the time required to engage a target and of increasing the probability of hit of an armoured fighting vehicle in a defensive and offensive posture. The results show that the effectiveness of the vehicle consistently and significantly improved as the time to engage a target decreased and as the probability of hit increased. The results also showed that decreasing the time to engage a target had a greater impact than increasing the probability of hitting it. Considering the fact that probability of hit is also range dependent, the study recommends that technologies that decrease the time required to engage a target be given a higher priority to those that increase the probability of hit.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Engagement Time
Hit Probability
Parametric Analysis
Armoured Fighting Vehicle
Vehicle Effectiveness